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Coherent time averaging is widely used in the study of evoked responses as a technique for extracting coherent signals from incoherent noise. This paper is concerned with the problem of estimating, in real time, the signal and noise components in coherent time averages of sample functions of EEG alpha activity in the presence and in the absence of coherent trains of photic stimuli.

The rationale for using a coherent time averaging algorithm in the study of evoked potentials is well known and seemingly straight-forward: events in each sample function that are coherent with the time base of the averager (i.e., bear a consistent temporal relationship to the trigger) will be enhanced by averaging (or summing) whereas incoherent or random events will tend to cancel out. The implication is that when a small signal is mixed with a lot of noise, the signal can be extracted by averaging a sufficiently large number of sample functions. However, in the case of electrophysiological potentials, neither the signal characteristics nor the signal-to-noise ratio is known; consequently, it is not clear how to select the best number of sample functions to include in the ensemble average. It is also unfortunate that the probability that a physiological process will remain stationary throughout the averaging time decreases as the averaging time increases. Thus, in an attempt to compensate for a low signal-to-noise ratio by increasing the number of sample functions in the average, the experimenter may be thwarted by significant non-stationarity. Similarly, from a control theoretical point of view, the experimenter is in a double bind: a compromise must be reached between the desire to avoid decisions based on insufficient data and the conflicting desire to maintain the shortest possible feedback loop. We have sought to minimize these problems by developing a real time signal-to-noise estimation algorithm.

We have used a LINC-8 computer for implementation of our estimation scheme and for analyzing the coherent changes in the EEG alpha rhythm in response to coherent trains of 10 microsec photic flashes (Grass PS-2 photostimulator at intensity #4) delivered through closed eyelids. The inter-flash period was set equal to the mean period of the autonomous alpha rhythm as measured by autocorrelation. Individual right and left occipital scalp electrodes were referred to the yoked ear-lobe electrodes. The cortical potentials were amplified, filtered (bandpass=5 Hz with 24 db per octave roll-off), and converted into digital form at a 1 msec sampling rate. Each sample function was 175 msec duration and was always synchronous with a flash at  $T_0$ . The average amplitude of the detected peaks was measured. This value was treated as the maximum signal contribution to the average to be expected if the signal were fully coherent. The discrepancy between the coherent prediction and the obtained average was treated as noise. The ratio of signal to the combined signal and noise estimates was re-computed as each new sample function was entered into the average.

An analog voltage proportional to this ratio was immediately output and displayed on a storage oscilloscope. Figure 1 shows the superimposed

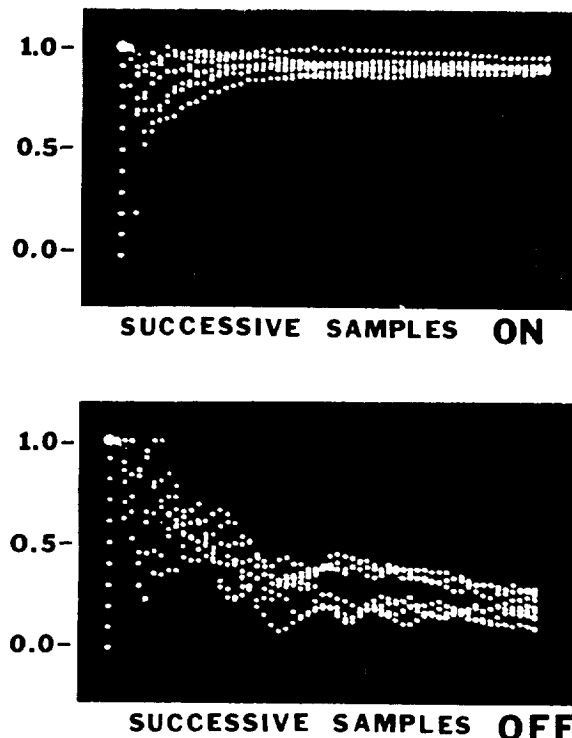


FIGURE 1. Signal / (Signal + Noise) Ratios

successive ratio values for seven 58-sample function averages of stimulus-ON (top) and the same number of sample functions for the stimulus-OFF condition (bottom). The successive ratios for a single cumulative average constitute a sort of "stabilization pathway" for the average. It is readily apparent in these records that there is greater redundancy as the number of sample functions in the average increases, and that there is a large difference between the stimulus-ON and stimulus-OFF conditions. Consequently, we believe that this estimation scheme holds considerable potential for quantitative, fully automatic assessments of signal and noise components in this type of evoked response.

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